REPORT DOCUMENTATION PAGE

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Robust Modeling of Complex Systems with heavy tails and long memory	W911NF-10-1-0289
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14. ABSTRACT

We study non-standard, non-Gaussian stochastic models, emphasizing their large deviations, extreme values, statistical features and dependence properties with applications to several kinds of risk and complex systems. We focus on structural and distributional properties that explain critical relationships and promote realistic fitting of the models to data. Applications areas are complex networks including data networks, reliability estimation, risk analysis and financial control. The models are typically non-Gaussian, often driven by

15. SUBJECT TERMS

complex systems, heavy tails, infinite variance, long memory, multivariate power laws, risk, large deviation, Markov conditioning

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Report Title

Robust Modeling of Complex Systems with heavy tails and long memory

ABSTRACT

We study non-standard, non-Gaussian stochastic models, emphasizing their large deviations, extreme values, statistical features and dependence properties with applications to several kinds
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explain critical relationships and promote realistic fitting of the models to data.
Applications areas are complex networks including data networks, reliability estimation, risk analysis and financial control. The models are typically non-Gaussian, often driven by
Poisson or Levy noises, may possess heavy tails and/or long range
dependence and exhibit unusual fractal and scaling behavior.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received   Paper

04/09/2012 18.00   Martin Larsson, Sidney I. Resnick. Extremal dependence measure and extremogram: the regularly varying case,
Extremes, (06 2011): 0. doi: 10.1007/s10687-011-0135-9

04/10/2012 9.00   Yann Demichel, Anne Estrade, Marie Kratz, Gennady Samorodnitsky. How Fast can the Chord-Length Distribution Decay?,
Advances in Applied Probability, (10 2011): 0. doi:

07/14/2014 41.00   Abhimanyu Mitra, Sidney I. Resnick. Modeling multiple risks: hidden domain of attraction,
Extremes, (03 2013): 0. doi: 10.1007/s10687-013-0171-8

07/14/2014 44.00   Sidney I. Resnick, David Zeber. ASYMPTOTICS OF MARKOV KERNELS AND THE TAIL CHAIN,
Advances in Applied Probability, (03 2013): 186. doi:

07/14/2014 43.00   Sidney I. Resnick, David Zeber. Clustering of Markov chain exceedances,
Bernoulli, (09 2013): 0. doi: 10.3150/12-BEJSP08

07/14/2014 42.00   Sidney I. Resnick, David Zeber. Transition kernels and the conditional extreme value model,
Extremes, (03 2014): 0. doi: 10.1007/s10687-014-0182-0

07/15/2014 45.00   Gennady Samorodnitsky, Yi Shen. Distribution of the supremum location of stationary processes,
Electronic Journal of Probability, (06 2012): 1. doi: 10.1214/EJP.v17-2069

07/15/2014 46.00   François Roueff, Gennady Samorodnitsky, Philippe Soulier. Function-indexed empirical processes based on an infinite source Poisson transmission stream,
Bernoulli, (08 2012): 783. doi: 10.3150/11-BEJ367

07/15/2014 47.00   Arijit Chakrabarty, Gennady Samorodnitsky. Understanding Heavy Tails in a Bounded World or, is a Truncated Heavy Tail Heavy or Not?,
Stochastic Models, (01 2012): 109. doi: 10.1080/15326349.2012.646551

07/15/2014 48.00   Gennady Samorodnitsky, Yi Shen. Is the location of the supremum of a stationary process nearly uniformly distributed?,
The Annals of Probability, (09 2013): 3494. doi: 10.1214/12-AOP787

07/15/2014 49.00   J. Peterson, G. Samorodnitsky. Weak weak quenched limits for the path-valued processes of hitting times and positions of a transient, one-dimensional random walk in a random environment,
Latin American Journal of Probability and Mathematical Statistics, (06 2012): 531. doi:

08/29/2011 7.00   Thomas Mikosch, Zbinek Pawlas, Gennady Samorodnitsky. A large deviation principle for Minkowski sums of heavy-tailed random compact convex sets with finite expectation,
Advances in Applied Probability, (08 2011): 133. doi:

08/29/2011 19.00   Sidney I. Resnick, Bikramjit Das. Conditioning on an extreme component: Model consistency with regular variation on cones,
Bernoulli, (02 2011): 226. doi: 10.3150/10-BEJ271

08/29/2011 12.00   Gennady Samorodnitsky, Arijit Chakrabarty. Understanding heavy tails in a boundedworld or, is a truncated heavy tail heavy or not?,
Stochastic Models, (12 2011): 0. doi:

08/29/2011 10.00 Thomas Mikosch, Zbinek Pawlas, Gennady Samorodnitsky. Large deviations for Minkowski sums of heavy-tailed generally non-convex random compact sets,
Verstnik of St. Petersburg University, (10 2011): 0. doi:

08/29/2011 8.00 Anders Jessen, Thomas Mikosch, Gennady Samorodnitsky. Prediction of outstanding payments in a Poisson cluster model,
Scandinavian Actuarial Journal , (09 2011): 0. doi:

09/20/2011 6.00 Gennady Samorodnitsky, Sami Umut Can, Thomas Mikosch. Weak convergence of the function-indexed integrated periodogram for infinite variance processes
,
Bernoulli, (09 2010): 995. doi:

09/20/2011 11.00 Francois Roueff, Gennady Samorodnitsky, Philippe Soulier. Function-indexed empirical processes based on an infinite source Poisson transmission stream,
Bernoulli, (11 2010): 995. doi:

09/20/2012 28.00 Jonathon Peterson, Gennady Samorodnitsky. Weak weak quenched limits for the path-valued processes of hitting times and positions of a transient, one-dimensional random walk in a random environment,
Latin American Journal of Probability and Mathematical Statistics, (12 2013): 0. doi:

09/20/2012 27.00 Robert Adler, Elina Moldavskaya, Gennady Samorodnitsky. On the existence of paths between points in high level excursion sets of   Gaussian random fields,
Annals of Probability, (04 2013): 0. doi:

09/20/2012 29.00 Thomas Mikosch, Gennady Samorodnitsky, Laleh Tafakori. Fractional moments of solutions to stochastic recurrence equations,
Advances in Applied Probability, (12 2013): 0. doi:

10/01/2012 35.00 Bikramjit Das, Abhimanyu Mitra, Sidney Resnick. Living on the multi-dimensional edge: seeking hidden risks using regular variation,
Advances in Applied Probability, (03 2013): 0. doi:

10/01/2012 34.00 Sidney Resnick, David Zeber. Asymptotics of Markov kernels and the tail chain,
Advances in Applied Probability, (03 2013): 0. doi:

   TOTAL: **23**

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received   Paper

09/04/2013 39.00 Richard A. Davis, Oliver Pfaffel, Robert Stelzer. Limit theory for the largest eigenvalues of samplecovariance matrices with heavy-tails,
Stochastic Processes and their Applications, (10 2012): 0. doi:

   TOTAL: **1**

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Samorodnitsky
THE EXISTENCE OF PATHS BETWEEN POINTS IN HIGH LEVEL EXCURSION SETS OF GAUSSIAN RANDOM FIELDS;
INTERNATIONAL CONFERENCE ON "GEOMETRY AND PHYSICS OF SPATIALLY RANDOM STRUCTURES"
FREUDENSTADT, GERMANY
Keynote Address
September 9, 2013

CENTRAL LIMIT THEOREM FOR HEAVY TAILED STATIONARY INFNITELY DIVISIBLE PROCESSES GENERATED BY
CONSERVATIVE FLOWS;
7TH INTERNATIONAL CONFERENCE ON L'EVY PROCESSES: THEORY AND APPLICATIONS
WROCLAW, POLAND
Invited Presentation
July 15, 2013

EXISTENCE OF PATHS BETWEEN POINTS IN HIGH LEVEL EXCURSION SETS OF GAUSSIAN RANDOM FIELDS;
8TH INTERNATIONAL CONFERENCE ON EXTREME VALUE ANALYSIS, SHANGHAI
Conference Presenter/Organizer
July 8, 2013

EXCURSION SETS OVER HIGH LEVELS OF NON-GAUSSIAN INFINITELY DIVISIBLE RANDOM FIELDS: EXTREME VALUE,
ALGEBRA, AND GEOMETRY;
"RANDOM FIELDS: GEOMETRY AND ERGODIC PROPERTIES"
Paris
Conference Presenter/Organizer
June 26, 2013

"FUNCTIONAL CENTRAL LIMIT THEOREM FOR HEAVY TAILED STATIONARY INFINITELY DIVISIBLE PROCESSES
GENERATED BY CONSERVATIVE FLOWS"
AND
"ON THE EXISTENCE OF PATHS BETWEEN POINTS IN HIGH LEVEL EXCURSION SETS OF GAUSSIAN RANDOM FIELDS";
UNIVERSITY OF LORRAIN, NANCY,
Guest Speaker
June 10, 2013

"FUNCTIONAL CENTRAL LIMIT THEOREM FOR HEAVY TAILED STATIONARY INFINITELY DIVISIBLE PROCESSES
GENERATED BY CONSERVATIVE FLOWS;
UNIVERSITY OF TENNESSEE, KNOXVILLE
Guest Speaker
April 11, 2013

FUNCTIONAL CENTRAL LIMIT THEOREM FOR HEAVY TAILED STATIONARY INFINITELY DIVISIBLE PROCESSES
GENERATED BY CONSERVATIVE FLOWS;
TECHNION
Guest Speaker
March 13, 2013

UNCTIONAL CENTRAL LIMIT THEOREM FOR HEAVY TAILED STATIONARY INFINITELY DIVISIBLE PROCESSES
GENERATED BY CONSERVATIVE FLOWS;
UNIVERSITY OF ALABAMA AT BIRMINGHAM MATHEMATICS COLLOQUIM
UNIVERSITY OF ALABAMA AT BIRMINGHAM
Conference Presenter/Organizer
January 24, 2013

FUNCTIONAL CENTRAL LIMIT THEOREM FOR HEAVY TAILED STATIONARY INFINITELY DIVISIBLE PROCESSES
GENERATED BY CONSERVATIVE FLOWS;
WORKSHOP ON HEAVY-TAILED DISTRIBUTIONS AND EXTREME VALUE THEORY
KOLKATA
Invited Presentation
January 14, 2013

THE EXISTENCE OF PATHS BETWEEN POINTS IN HIGH LEVEL EXCURSION SETS OF GAUSSIAN RANDOM FIELD;
Conference on Limit Theorems in Probability
Bangalore

Invited Presentation
January 9, 2013

Resnick
The Art of Seeking Hidden Risks;
The 59th World Statistics Congress
Hong Kong, China
Conference Presenter
August 25, 2013

Asymptotic Methods for Extremal Dependence; Where did the jumps go?
Building Bridges: Probability, Statistics and Applications on the occasion of the International Year of Statistics   2013 and with special events commemorating the 60th birthday of Claudia Klueppelberg
Braunschweig, Germany
Invited Presentation
August 12, 2013

Asymptotic Methods for Extremal Dependence
Extremal Dependence Workshop
Columbia University, New York City, NY
Workshop Presenter
May 3, 2013

Why is Traffic at a Busy Hub Gaussian? Modeling Data Network Sessions
Columbia University, Dept of IEOR,
Seminar Presenter
March 13, 2013

The Art of Seeking Hidden Risks
Symposium in Honor of Prof. Dr. Paul Embrechts on the Occasion of his 60th Birthday
ETH Zurich
Symposium Presenter
February 15, 2013

Why is Traffic at a Busy Hub Gaussian
Modeling Data Network Sessions
Tulane University, Seminar, Dept of Mathematics
February 3, 2013

The Art of Seeking Hidden Risks
Workshop on Heavy tailed distributions and extreme value theory
Kolkatta, India. Invited lecture.
January 14, 2013

The Multidimensional Edge: Seeking Hidden Risks
McGill University, Department of Math and Statistics
Montreal October 2012

The Multidimensional Edge: Seeking Hidden Risks
Colorado State University, Seminar, November 11, 2012.

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received   Paper

03/28/2012 26.00   Gennady Samorodnitsky, Yi Shen. Distribution of the supremum location of stationary processes,
Electronic Journal of Probability (10 2011)

03/28/2012 25.00   Gennady Samorodnitsky, Yi Shen. Is the location of the supremum of a stationary process nearly
uniformly distributed?,
Annals of Probability (10 2011)

08/28/2011   3.00   Bikramjit Das, Abhimanyu Mitra, Sidney Resnick. LIVING ON THE MULTI-DIMENSIONAL EDGE:
SEEKING HIDDEN RISKS USING REGULAR VARIATION,
Submitted (08 2011)

08/28/2011   5.00   Luis Lopez-Oliveros, Sidney Resnick. ON THE SUPERPOSITION OF HETEROGENEOUS TRAFFIC AT
LARGE TIME SCALES ,
Stochastic Systems (08 2011)

09/13/2013 40.00   Richard Davis, Oliver Pfaffel. EIGENVALUES OF SAMPLE COVARIANCE MATRICES OF NON-
LINEARPROCESSES WITH INFINITE VARIANCE,
http://arxiv.org/abs/1211.5902 (11 2012)

09/20/2011 13.00   Gennady Samorodnitsky, Jonathon Peterson. Weak quenched limiting distributions for transient one-
dimensional random walk in a random environment,
Annals de L'Institut d'Henri Poincare (09 2011)

09/20/2011 14.00   Gennady Samorodnitsky, Tilo Nguyen. Tail Inference: where does the tail begin?,
Extremes (09 2011)

09/20/2012 31.00   Takashi Owada, Gennady Samorodnitsky. Functional Central Limit Theorem for Heavy Tailed Stationary
Infinitely Divisible Processes Generated by Conservative Flows,
Annals of Probability (09 2012)

09/20/2012 30.00   Gennady Samorodnitsky, Yi Shen. Intrinsic Location Functionals of Stationary Processes,
Stochastic Processes and their Applications (06 2012)

09/21/2011 20.00   S. Resnick, A. Mitra. MODELING TOTAL EXPENDITURE ON WARRANTY CLAIMS,
Stochastic Models (09 2011)

09/21/2011 21.00   S. Ghosh, S. Resnick. WHEN DOES THE MEAN EXCESS PLOT LOOK LINEAR? ,
Stochastic Models (09 2011)

09/21/2011 22.00   A. Mitra, S. Resnick. HIDDEN REGULAR VARIATION AND DETECTION OF HIDDEN RISKS,
Stochastic Models (09 2011)

10/01/2012 37.00   Abhimanyu Mitra, Sidney Resnick. MODELING MULTIPLE RISKS: HIDDEN DOMAIN OF ATTRACTION,
Extremes (pending) (08 2012)

10/01/2012 32.00   Sidney Resnick, David Zeber. Clustering of Markov Chain Exceedances,
Bernoulli (submitted) (09 2012)

10/04/2012 38.00   Joyjit Roy, Sidney Resnick. Maxima of bivariate triangular arrays: Between asymptotic complete
dependence and asymptotic independence lies the conditional extreme value model,
Draft (11 2012)

TOTAL: **15**

Number of Manuscripts:

Books

Received   Book

     TOTAL:

Received   Book Chapter

     TOTAL:

Patents Submitted

Patents Awarded

Awards

Samorodnitsky served as head of Cornell's Center for Applied Math.

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Joyjit Roy	0.08	
Yi Shen	0.08	
Takashi Owada	0.08	
FTE Equivalent:	**0.24**	
Total Number:	**3**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Sidney Resnick	0.08	
Gennady Samorodnitsky	0.08	
FTE Equivalent:	**0.16**	
Total Number:	**2**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Student Metrics
This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields: 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields: 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale): 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering: 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME
Tilo Nguyen
Yi Shen
Takashi Owada
Luis Lopez-Oliveros
David Zeber
Abhimanyu Mitra
Total Number: 6

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

1. Forward
Professors Samorodnitsky and Resnick, as well as their students continued studies related to
effects of heavy tails and dependence as well as inferential techniques
and applications to risk estimation, data network modeling and control
and insurance.

2. David Zeber completed his thesis and 3 papers devoted to understanding heavy tailed Markov processes while completing a treatment of the approximation known as the tail chain. This comprehensive treatment also informed understanding of the clustering of exceedences for such a process without resort to assumptions of stationarity. This was related to the conditional extreme value model studied earlier by Resnick, Das, Heffernan, Mitra.

3. We completed the study of the role of Gaussian distributions in heavily loaded networks and made a link with real data to find the cause of the ubiquity of the Gaussian assumption.

4. Yi Shen completed a thesis that studied the extremal properties of a continuous time stationary process. This included a thorough understanding of the functional locating the time at which the path achieves its maximum value. More generally for random fields, techniques were developed to study high level excursion sets with applications to spatial processes such as those used in brain mapping.

5. A general formulation of multivariate heavy tails was begun with sufficient flexibility to allow multiple asymptotic regimes within the same model. Initial results for diagnosing such a situation were proposed. These results have recently matured under the current MURI grant. The ability to assess risk under trying circumstances was enhanced.

6. Techniques were developed in the thesis of T. Owada guided by Samorodnitsky which quantify effects of dependence for infinitely divisible processes. The concept of a tail measure was used to approximate quite complicated probabilities of extreme sets.

7. Mitra completed a series of papers discussing various aspects of hidden regular variation and hidden domain of attraction. This is a concept supporting the idea that simultaneous asymptotic regimes coexist in one problem. In real data they must be diagnosed and used to advantage.

8. Tilo Nguyen studied the issue of threshold selection for tail inference in both the univariate and multivariate cases of heavy tails.

9. Samorodnitsky and coworkers studied fractional moments of solutions of stochastic recurrence equations common in econometrics. Samorodnitsky & Bladt also developed methods for computing ruin probabilities for difficult class of problems.

Technology Transfer